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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

01480013.0

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

I.L.C. HATTEN-HECKMAN

DEN HAAG, DEN
THE HAGUE, 04/05/01
LA HAYE, LE

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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

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Demande n°:

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INTERNATIONAL BUSINESS MACHINES CORPORATION
Armonk, NY 10504
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System and method for enabling a collision-free protocol over ethernet

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SYSTEM AND METHOD FOR ENABLING A COLLISION-FREE PROTOCOL OVER ETHERNET

Field of the Invention

The present invention relates to Local Area Networks (LANs) and more particularly applies to those of LANs operating with a 'Carrier Sense, Multiple Access, Collision Detect' or CSMA/CD protocol i.e., Ethernet LANs.

Background of the Invention

Ethernet is a local area network (LAN) technology that allows to transmit information between computers at speeds of 10 million bits per second (Mbps), 100 Mbps (Fast Ethernet) and, more recently, one gigabit ($x10^9$) bits per second.

Ethernet assumes that an unlimited number of devices can be connected on a shared transmission medium including a thick coaxial, in the original 10 Mbps Ethernet, as well as thin coaxial, twisted-pair, and fiber optic media in the newer versions. To control the exchange of data between the stations connected on the shared medium, Ethernet uses a protocol called CSMA/CD. This stands for 'Carrier Sense, Multiple Access, Collision Detect'. The 'Multiple Access' part means that every station is indeed connected to the shared transmission forming a single data path. The 'Carrier Sense' part says that before transmitting data, a station checks it to see if any other station is already sending something. If the transmission medium appears to be idle then, the station can actually begin to send data. However, two stations can start transmitting at the same time, causing a collision. When this occurs, each interfering station is made able to detect it. Hence, all stations attempting to transmit, back off, and try a retransmission at randomly selected later times thus minimizing the chance of another collision.

This simple mechanism to implement LANs has had a great success and has been universally adopted. Indeed, a majority of installed LANs throughout the world are actually Ethernet LANs thus, follow the corresponding IEEE (Institute of Electrical and Electronics Engineers) standard i.e., IEEE 802.3.

Although Ethernet does not set an upper limit to the number of stations that can be connected on a same transmission medium there are, in practice, drastic limitations. Generally speaking, as more users are added to a shared network or, as applications requiring more data are added, performance inevitably deteriorates. This is because all users become competitors in trying to use a common resource: the shared transmission medium. It is generally agreed that, on a moderately loaded 10 Mbps Ethernet network, being shared by 30-50 users, network can only sustain throughput in the neighborhood of 2.5 Mbps after accounting for packet overhead, inter packet gaps and collisions resulting of the use of the here above CSMA/CD protocol.

Thus, yet simple, CSMA/CD protocol, suffers drastic limitations in its ability to take advantage of the intrinsic performance of the shared transmission medium i.e., 10 Mbps in this example. Further increasing the number of users (and therefore packet transmissions) creates an even higher collision potential. Since collisions occur when two or more stations attempt to send information at the same time, when these latter realize that a collision has occurred, they must, to obey standard, all shut off for a random time before attempting another transmission. This tends to add a considerable overhead, severely impacting performance, until the mechanism just collapses when medium is attempted to be too much utilized.

One well-known solution to alleviate this problem is to segment traffic over, independent, disjoint, smaller collision domains however, at the expense of having to put in place extra devices to allow communication between the independent pieces thus created of a LAN. This may be a bridge, a hub or a switch. For example, an eight-port high-speed switch can support eight Ethernets, each running at a full 10 Mbps so as to be able to interconnect more users on what appear however to them as a single LAN. Thus, at the expense of creating a more expensive and complicated network which goes against the original objectives of the Ethernet LAN that wanted to be a very inexpensive solution, simple to deploy and to administrate for local communications typically, over a campus or between the employees of a company dispersed over a group of buildings.

Another technology for LAN is Token Ring. It is described in IEEE standard 802.5 and based on the circulation of a token between stations. Each station must wait for the token in order to be authorized to transmit on the shared medium here referred to as a ring thus, completely getting rid of the collision problem here above discussed. Indeed, this has proved to allow a better utilization of the shared medium. On the other hand, token ring technology is more expensive, more complex, and therefore less spread in today's LAN networks.

Objects of the Invention

Thus, it is a broad object of the invention to provide an improved, collision-free, Ethernet technology.

It is another object of the invention to allow that this improved Ethernet be useable over the current inexpensive, highly utilized, and well-known CSMA/CD Ethernet network infrastructure.

It is a further object of the invention to permit that the passing-token mechanism of the Token Ring LANs be efficiently carried out over existing Ethernet networks so as a physical Ethernet network becomes collision free, and therefore can be utilized at higher rates.

It is yet another object of the invention to permit that collision and collision-free mechanisms can coexist on a single Ethernet network.

Further objects, features and advantages of the present invention will become apparent to the ones skilled in the art upon examination of the following description in reference to the accompanying drawings. It is intended that any additional advantages be incorporated herein.

Summary of the Invention

A method and a system aimed at enabling a collision-free protocol for transmitting frames between stations connected over a shared transmission medium, of a type such as the ones complying with the IEEE 802.3 standard i.e., Ethernet LANs, are disclosed. The method assumes that a logical ring is formed between connected stations and that a token is circulated among those of the connected stations part of the logical ring (not all connected stations are required to be part of the ring). Hence, transmitting from any one station, part of the logical ring, is only permitted while holding the token thereby, preventing collisions from happening.

Thus, the invention allows that an improved, collision-free protocol, over a standard Ethernet infrastructure, becomes feasible yet remaining compatible with the standard collision protocol.

Brief Description of the Drawings

Figure 1 shows the placement of the new collison control sub-layer introduced by the invention.

Figure 2 depicts a logical ring per the invention.

Figure 3 shows the steps of the method for transmitting.

Figures 4 and 5 discuss how a logical ring is formed and managed through the addition and removal of stations.

Figure 6 discusses how to recover from a lost token.

Figure 7 shows the steps of the method for inserting a station.

Figure 8 shows the steps of the method for removing a station.

Figure 9 shows the steps of the method for checking the circulation of the token.

Detailed Description of the Preferred Embodiment

Figure 1 discusses the basic modification brought by the invention to the set of Ethernet protocols. The invention introduces a new sub-layer [100], just below the Logical Link Control (LLC) [112], the upper portion of the data link layer for local area networks of the Ethernet protocol as defined in IEEE 802.2. The LLC sub-layer is aimed at presenting a uniform interface to the user of the data link service i.e., the network layer or layer 3 [120] of the OSI reference model (a hierarchical structure of seven layers by the International Standards Organization that defines the requirements for communications between two computers). The network layer protocols establish, maintain and terminate end to end (network) links. These protocols route messages across the network(s) between two computer stations. When using the TCP/IP suite of protocols, the most largely used of all protocols for operating LANs, this role is played by the Internetwork or IP layer of the TCP/IP suite.

Beneath the LLC sub-layer there is normally the Media Access Control (MAC) [114] sub-layer defined in IEEE 802.3. LLC and MAC are part the OSI layer 2 or Data Link layer [110]. These protocols are aimed at providing reliability to the physical layer transmission by ordering the data into frames and adding error checking and addressing information. Layer 1 or physical layer [130] is responsible for establishing, maintaining and ending physical connections (point to point) [135] between computer stations.

Thus, the invention introduces a collision control sub-layer [100], in layer 2 [110], between MAC sub-layer [114] and LLC sub-layer [112], so as to prevent collisions from ever occurring. Its role is to manage a token, as shown in Figure 2, in order to grant a station the permission to transmit on the Ethernet segment. This requires the use of a transmit queue [102] in which frame(s) to be forwarded are temporarily held whenever it is necessary i.e., when a station does not

hold the token so that only one station connected on the shared transmission medium [135] is authorized to transmit at a time.

Figure 2 is a view of an Ethernet LAN segment where the stations [201, 202, 203] physically connected on the shared medium [210], exactly as with a regular collision Ethernet LAN, are organized so that they form a logical ring [220]. This is achieved through the circulation of a token [230] which takes the form of a special Ethernet frame [240], forwarded [231] from one station to a next one, e.g., from [201] to [202]. Token is comprised of the following information:

- An Ethernet Destination MAC address [241] i.e., the MAC address of the next ring station, [202] in this example.
- An Ethernet Source MAC address [242] i.e., the MAC address of the station sending the token, [201] in this example.
- A destination SAP (Service Access Point) [243] which, in the OSI model already mentioned, is due to identify the individual application on a host which is sending a packet. A destination SAP address [243] of 0xAA is however used here which is the standard way of actually defining the type of application in the following SNAP (SubNetwork Access Protocol) field.
- A source SAP [244], i.e., the counter part of the here above destination SAP. It takes a value of 0xAA too.
- A control field [245] which takes the value of 0x03 to indicate this is a UI (Unnumbered Information) frame.

The five above fields are the standard Ethernet MAC [241, 242] and LLC [243, 244, 245] header fields. They are not specific to the invention. Only the two following fields are specific:

- A SNAP 5-byte header field introducing a new Ether-type i.e., a collision-free Ethernet ring [246].
- A 1-byte token field [247] to help managing the circulation of the token however, not mandatory, and which takes a default value of 0x00.

Therefore, the token is a standard Ethernet frame uniquely identified through its SNAP field [246]. Its sole possession, by a station, is thus the implicit permission to use the shared transmission medium on which a functional frame can be placed before token is passed to the next station in sequence.

Hence, logical ring [220] is just a list of stations pertaining to the ring. Actually, each station needs only to hold a record of the next and previous station identifiers (ID) [250] e.g., under the form of their MAC addresses. Thus, when a station like [201] has got the token, it is allowed to transmit one and only one frame destined to another station (if it has indeed something to transmit) while holding it. Transmission [265] is simply achieved by placing the functional frame [260] on the shared transmission medium [210] irrespective of its mode of propagation (unicast, multicast or broadcast) so that the receiving station(s), that are listening, can catch it. At completion of transmission, station that currently holds the token [201], must forward it [231] through the shared transmission medium, to the next one in sequence of the logical ring, i.e., [202] in this particular example, using the MAC address found in an associated record similar to [250] and so on.

It is worth noting here that not all stations connected on the same LAN segment need to participate into the collision-free ring [220] thus formed. The invention assumes that both type of protocols (collision and collision-free) may coexist at any given instant so that a station like [204] needs not to implement the new protocol while still being able to communicate with all the others connected on the shared transmission medium [210] however, using the regular collision protocol.

Figure 3 shows the steps of the method executed in any of the station pertaining to a ring in order to transmit a frame over the shared transmission medium. A station keeps waiting [300] as long as it does not hold the token. When station holds the token (because it received it from previous station in the ring), so as answer to question [310] is positive, next step [320] is to check if at least one frame is ready to go i.e., if transmit queue is non-empty. If there is indeed something to transmit [322] then, the first or only frame ready to go is de-queued and placed on the shared transmission medium [330]. Irrespective of the fact that queue is empty [321] or not [322] next step consists in retrieving the ID of the next station in sequence in the ring [340] i.e., the station to which the token must be in turn transmitted [350]. At completion of this step, transmit method unconditionally resumes at step [310], waiting until token is received again after having gone through all the other stations participating into the ring.

Figure 4 discusses the insertion of a new station [404] into the ring [420] when, e.g., a computer is connecting onto the Ethernet transmission medium [410] or because computer is turn on. Figure 4 assumes that ring [420] is already formed and that a 'Ring Manager' (RM) [403] has been previously elected. This aspect of the invention is further discussed in following figures. Then, the new connecting station [404] must first issue a 'Ring Insert Request' (RIR) message [464]. This can be achieved under the form of a broadcast message, that all stations will receive, and on which only RM will act on. It may be, as well, a message to a predefined functional address (part of the collision-free protocol definition) so that all connecting stations, which know in advance this functional address, use it to send RIR directly to an assumed RM. Upon sending RIR message connecting station also triggers a 'Ring Insert Timer' (RIT) [474]. After which it waits for an answer from RM [403]. At this stage there are three

possibilities listed hereafter. Only the second one is actually illustrated by Figure 4, i.e., when insertion into an already formed ring is indeed successful, which is the common case.

- RIT [474] expires without any response received from an assumed RM. Then, connecting station [404] must assume it is the first to connect or the first to want to form a ring. Hence, this first connecting station must elect itself as a RM. This is also further discussed in next figures.

- An existing RM [403] indeed responds, as illustrated in the example of this figure, with a 'Ring Insert Granted' (RIG) message [463]. This latter includes the MAC addresses of the next station [403] (i.e., RM itself) and the one of the previous station on the logical ring [402], from where the new station [404] is thus to be inserted. These are the addresses that the new inserted station will have to use now on when passing token as explained previously in Figure 2. Obviously, a corresponding modification must also be done in the station that used to be located just before RM in the ring, namely [402]. Hence, RM forwards it a 'Ring Insert Update' (RIU) message [473] too. Upon receiving this message station [402] must update its next station address (from RM to the one of the new inserted station). Finally, the new inserted station acknowledges the insertion by sending back, directly to RM, a 'Ring Insertion Acknowledgment' (RIA) message [484] so as to end successfully the insertion process. At completion of it ring [420] that included stations [403, 401, 402] now also includes station [404] forming a new larger ring [421].

• A 'Ring Insertion Denied' (RID) message is received in place of a RIG message by the connecting station (this is not however illustrated in Figure 4). In this case the new connecting station must resume with a new complete insertion process as explained above. This is needed to take care of the border cases when two computers are trying to connect at the same time in order to avoid that both could be elected as RM. This is also further discussed in the rest of the description.

Figure 5 first discusses the general case of the removal of a station from a formed ring [521]. This is simply achieved, from the station to be removed, which is due to inform the next and previous station on the logical ring before actually leaving the ring. If, for example, station [501] must leave the ring, currently comprised of the four stations [501, 502, 504, 503], leaving station must inform next station in sequence [502] with a 'Ring Removal Forward' (RRF) message [561]. Also, previous station [503] must be informed too, with a 'Ring Removal Backward' (RRB) message [571], so as ring is not broken. The end result is that removed station is, on completion of the removal process, skipped hence, resulting in the formation of a new ring [522].

Two special cases must also be considered:
Firstly, when leaving station is also the Ring Manager then, forwarded RRF message contains a flag. Thus, if leaving station [501] was indeed playing the role of Ring Manager it must add a flag [581] to RRF message it sends [561] so that the next station in sequence i.e., [502] in this example, is informed to take over the role of Ring Manager for the new updated ring [522] which is further discussed in Figure 8.
Secondly, if the leaving station is the last one (this was a 'single-station ring' which has obviously no practical interest and should normally be a transient state when a ring is being formed or is being disbanded) then, no messages need to be issued.

Figure 6 is aimed at discussing the loss (for whatever reason) of the token [630] by the ring [620]. This is potentially detectable by any station e.g., station [604] because every station is equipped with a 'Ring Token Timer' (RTT) [694] on top of RIT [674] previously discussed. If RTT elapses then, detecting station is due to issue (broadcast) a 'Ring Restart' (RR) message [654], destined to all other stations, so that the formation of the ring is restarted from scratch which is further discussed in Figure 7 hereafter.

Typically, token is lost whenever a station is powered off without executing the steps of the method discussed here after in Figure 8 and aimed at handling a proper removal that does not break the ring to which station used to be connected.

Figure 7 is the diagram that describes the steps of the method according to the invention when a station wants to join a ring. This usually happens [700] when a station is first initialized or reinitialized i.e., when a computer connected on the Ethernet LAN is turn on or is re-IPL'ed. Also, on reception of a 'Ring Restart' (RR) message (e.g., because token has been lost) all stations must resume their insertion process so as to form a new operative ring from scratch. And, insertion must also be re-attempted on reception of a 'Ring Insertion Denied' (RID) message. This situation may happen if a 'Ring Manager' (RM) has just been elected. This is further discussed hereafter. Then, the first action [710] of a station willing to join the ring is to issue a 'Ring Insert Request' (RIR) message and, simultaneously, to trigger a 'Ring Insert Timer' (RIT). If a RM is already present a 'Ring Insert Granted' (RIG) message [720] is normally soon received. In which case the station is actually inserted [730] thus, getting from RM the addresses of the next and previous stations of the ring that must be remembered by the new inserting station as already discussed in Figure 2. However, a Ring Insertion Denied (RID) message [740] may be received instead. If this is the case, it is the indication that a new ring is being formed and that another station was quicker to

elect itself as a RM however, had no time to answer the RIG message [720]. When this happens [741], on receiving a RID message, the station willing to insert must resume at initial step [700] so as to reissue a RIR message that will normally be answered by the new RM. The other possibility is that RIT expires [750]. When this occurs [752], it means there is no RM and that the inserting station must, now on, play this role [770]. Prior to this, or simultaneously, a RID message must be issued [760] so as no other station, engaged in the same process, could possibly self-elect as RM too. While none of the events of steps [720, 740, 750] are occurring the insertion mechanism is normally looping [751], waiting till any of them to actually occur. Hence, at completion of the insertion, the new station is inserted [730] and may possibly become the RM [770].

Figure 8 shows the steps of the method per the invention when a station must leave the ring. Removal of a station from the ring normally happens [800] when a computer is powered off, is disconnected from the LAN, or is re-IPL'ed. Then, as already discussed in Figure 5, leaving station has just, prior to leaving, to inform its next and previous ring stations it is going to remove itself from the ring thus, that they must update respectively their own previous and next stations so as ring is not broken. As explained, this is done by issuing two messages [830], i.e., a RRF message to next station in sequence and a RRB message to the previous one. However, if leaving station is the current RM [810] it must set the flag of the RRF message [820] so as the next station is informed to become the new RM.

Figure 9 is aimed at illustrating the steps of the method according to the invention that deals with the circulation of the token. Every station on the ring continuously monitors for the reception of the token [910]. Whenever it is received RT. is reset [900]. If not, RT. is checked [920]. If it has timed out this triggers the sending of RR message [930] so as to form a new ring since it is the indication that token is lost. If, as normally expected, RT. has not timed out [921] station keeps waiting token to show up.

Claims:

What is claimed is:

1. A method for enabling a collision-free protocol for transmitting frames [260] between a plurality of stations [201, 202, 203], said plurality of stations physically connected over a shared transmission medium [210], said method comprising the steps of:

forming a logical ring [220] among said plurality of stations;

circulating a token [230] between said plurality of stations part of said logical ring;

transmitting from any one station [265], part of said logical ring, only while holding said token [230];

thereby, preventing collisions from happening upon transmitting said frames over said shared transmission medium.

2. The method according to claim 1 wherein said shared transmission medium [210] is any Ethernet-like LAN (Local Area Network) segment employing a collision protocol for transmitting.

3. The method according to any one of the previous claims wherein said shared transmission medium is complying with the IEEE 802.3 standard.

4. The method according to any one of the previous claims including a collision control sub-layer [100] said collision control sub-layer comprising a transmit queue [102].

5. The method according to any one of the previous claims wherein said transmitting step includes, in said any one station part of said logical ring, the further steps of:

checking [310] whether said any one station holds said token or not;

if not:

keep waiting [300] till said token is received;

if holding said token:

checking [320] if said transmit queue is empty;

if empty [321]:

skipping following placing step;

if not empty [322]:

placing [330] a first or only frame from said transmit queue on said shared medium thus, transmitting said frame;

retrieving [340] an ID of an immediate next station in sequence in said logical ring;

forwarding [350] said token to said immediate next station;

resuming to first checking step [310];

thereby, waiting for a next occurrence of said token.

6. The method according to any one of the previous claims wherein said forming step includes, in a station willing to join said logical ring, the further steps of:

upon starting insertion [700] of said joining station,

issuing a RIR (Ring Insert Request) message [710] towards an assumed RM (Ring Manager);

starting a RIT (Ring Insert Timer) [710];

checking whether a RIG (Ring Insert Granted) message [720] is received or not;

if said RIG is received:
inserting [730] said joining station in said logical ring;

thereby, completing [780] said insertion of said joining station in said logical ring;

if said RIG is not received:
checking whether a RID (Ring Insert Denied) message [740] is received or not;

if said RID is received [741]:
restarting insertion [700] of said joining station;

if said RID is not received:
checking [750] if said RIT has elapsed;

if not [751], resuming at checking RIG step;

if yes [752], issuing said RID message [760];

self-electing [770] said joining station to play the role of RM;

thereby, completing [780] said insertion of said joining station acting as a RM of a new forming ring.

7. The method according to any one of the previous claims wherein said RM, upon issuing said RIG message towards said joining station, is also issuing a RIU (Ring Insert Update) message [473] to an immediate previous station [402] over said logical ring.

8. The method according to any one of the previous claims wherein said forming step includes, in a station willing to leave said logical ring, the further steps of:

upon starting removal [800] of said leaving station,

checking [810] whether said leaving station is said RM or not;

if not:

skipping following setting step;

if yes:

setting a flag [820] in a RRF (Ring Removal Forward) message;

issuing said RRF [830] to said immediate next station [502] of said logical ring;

issuing a RRB (Ring Removal Backward) message [830] to said immediate previous station [503] of said logical ring;

thereby, completing removal of said leaving station.

9. The method according to any one of the previous claims wherein said step of checking whether said any one station holds said token or not includes the further steps of:

checking [910] whether said token has been received or not:

if yes:

resetting a RTT (Ring Token Timer) [900];

keep cycling;

if not:

checking whether said RTT has elapsed or not [920];

if not elapsed:

keep cycling [921];

if elapsed:

issuing a RR (Ring Restart) message [930];

thereby, informing all stations of said logical ring to restart insertion [700].

10.A system, in particular a system implementing a logical ring over a collision LAN, comprising means adapted for carrying out the method according to any one of the previous claims.

11.A computer-like readable medium comprising instructions for carrying out the method according to any one of the claims 1 to 9.

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SYSTEM AND METHOD FOR ENABLING A COLLISION-FREE PROTOCOL OVER ETHERNET

Abstract

The invention discloses how a collision-free protocol, for transmitting frames between stations connected over a shared transmission medium such as an IEEE 802.3 Ethernet LAN, is carried out. Hence, a logical ring is formed and a token is circulated among the connected stations part of the logical ring (not all connected stations are required to be part of the logical ring). Thus, transmitting from any one station, part of the logical ring, is only permitted while holding the token therefore, preventing collisions from happening.

Then, a collision-free protocol, over a standard Ethernet infrastructure, becomes feasible, yet remaining compatible with the standard collision protocol thus, improving performances.

Figure 2.

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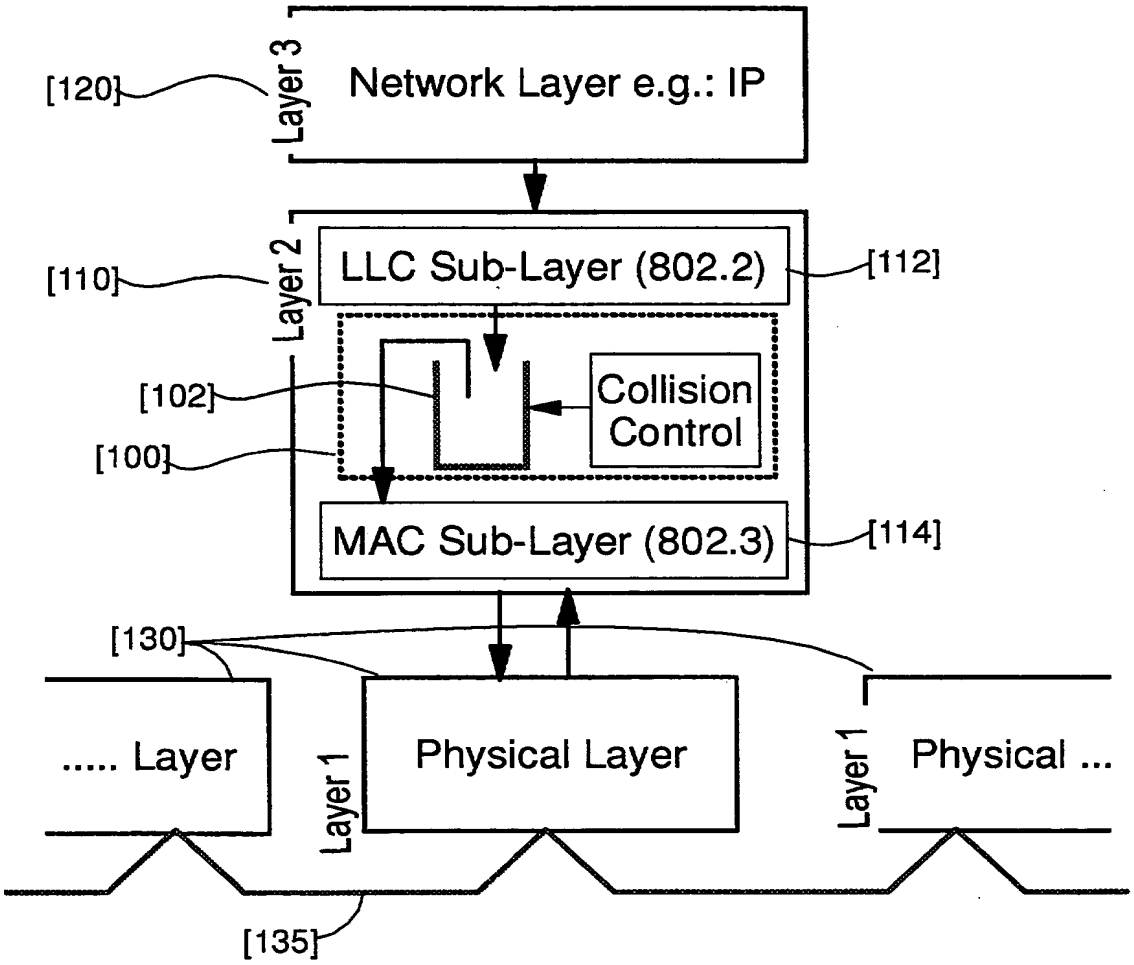
[120]
Layer 3
Network Layer e.g.: IP
[110]
Layer 2
LLC Sub-Layer (802.2)
[112]
[102]
Collision Control
[100]
MAC Sub-Layer (802.3)
[114]
[130]
..... Layer
Layer 1
Physical Layer
Layer 1
Physical ...
[135]

Figure 1

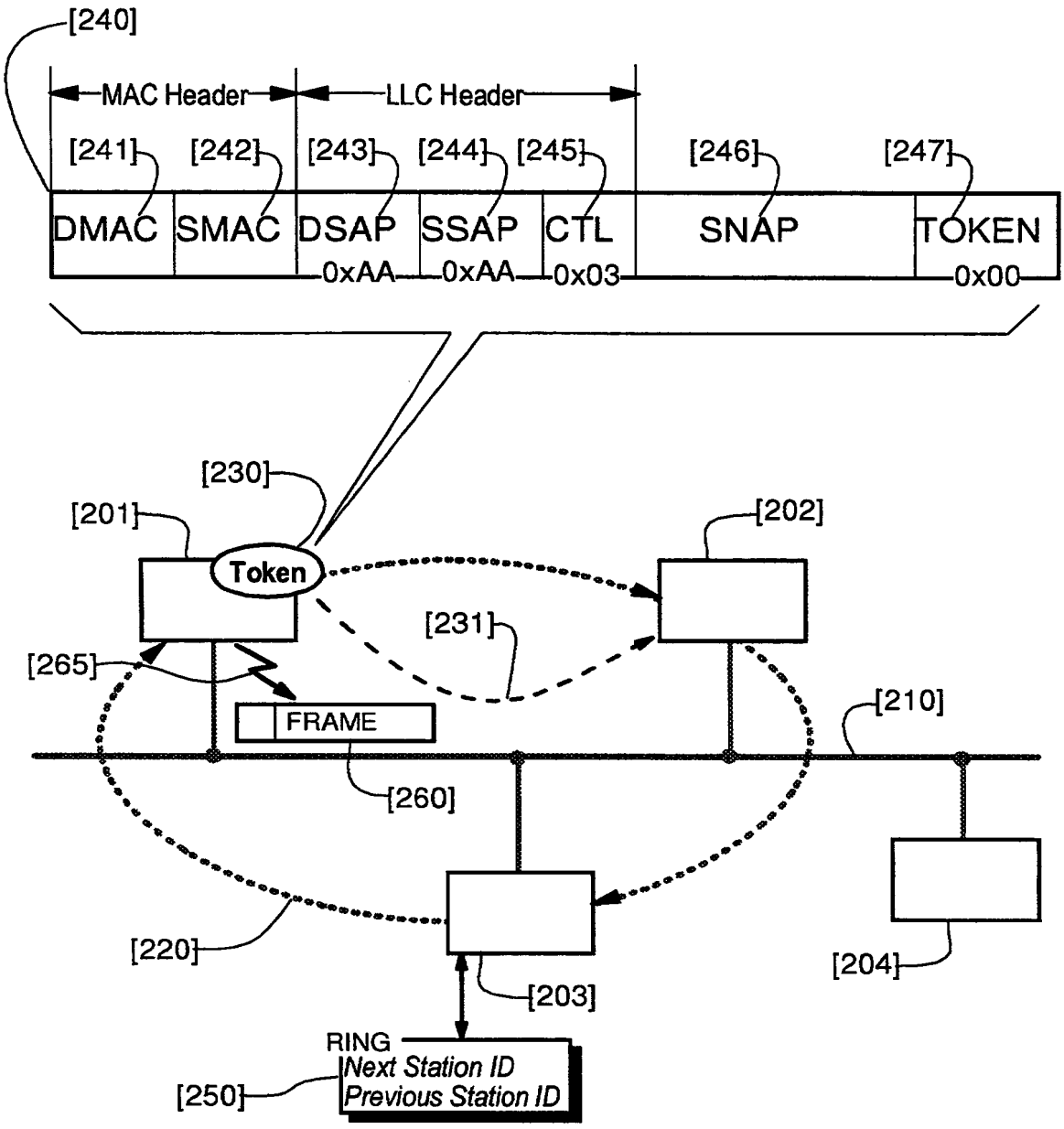
[240]
MAC Header
LLC Header
[241]
[242]
[243]
[244]
[245]
[246]
[247]
DMAC
SMAC
DSAP
SSAP
CTL
SNAP
TOKEN
0xAA
0xAA
0x03
0x00
[230]
[201]
[202]
Token
[231]
[265]
FRAME
[210]
[260]
[220]
[204]
[203]
RING
[250]
Next Station ID
Previous Station ID

Figure 2

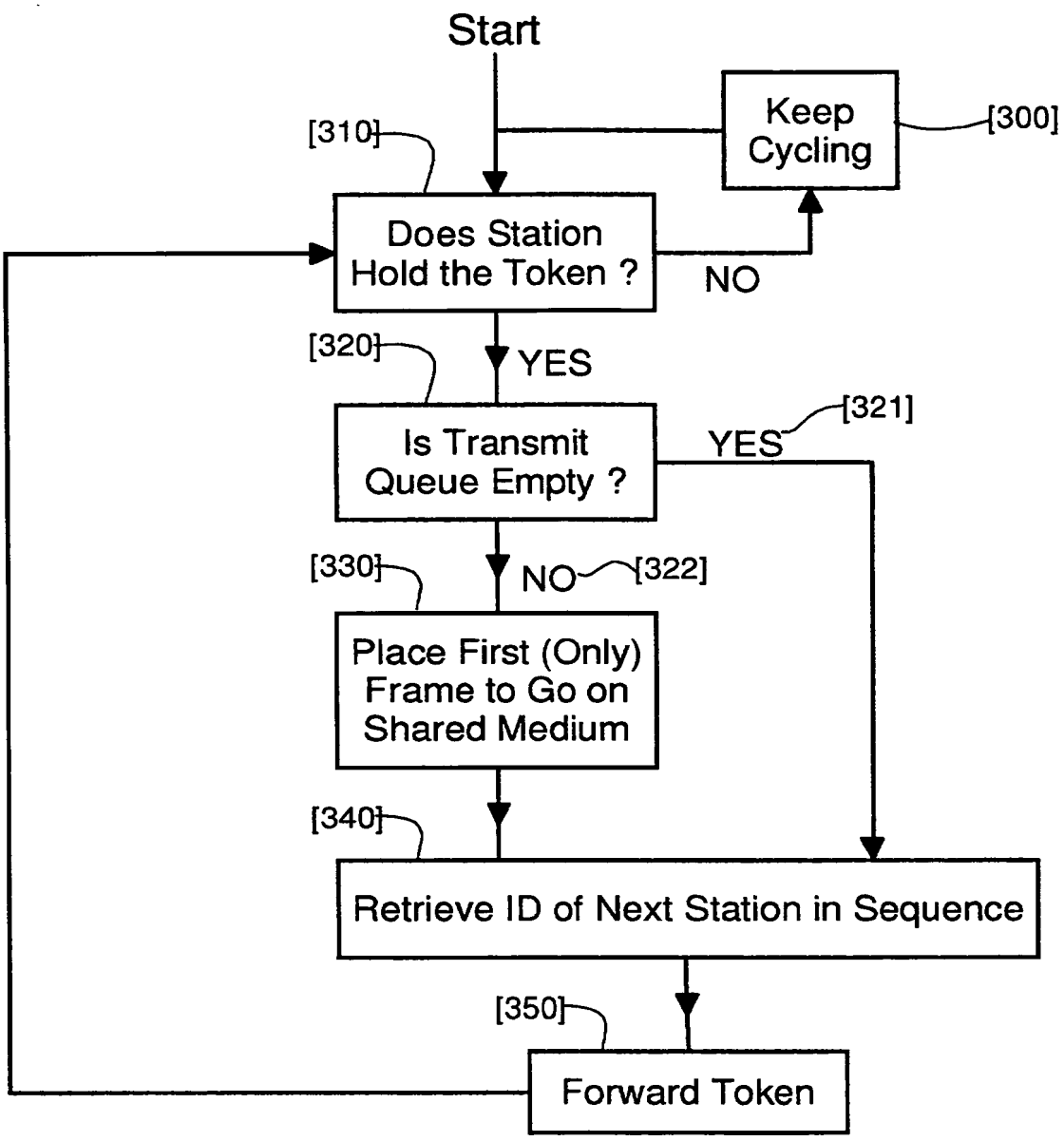
Start
Keep Cycling
[300]
[310]
Does Station Hold the Token ?
NO
[320]
YES
[321]
Is Transmit Queue Empty ?
YES
[330]
NO
[322]
Place First (Only) Frame to Go on Shared Medium
[340]
Retrieve ID of Next Station in Sequence
[350]
Forward Token

Figure 3

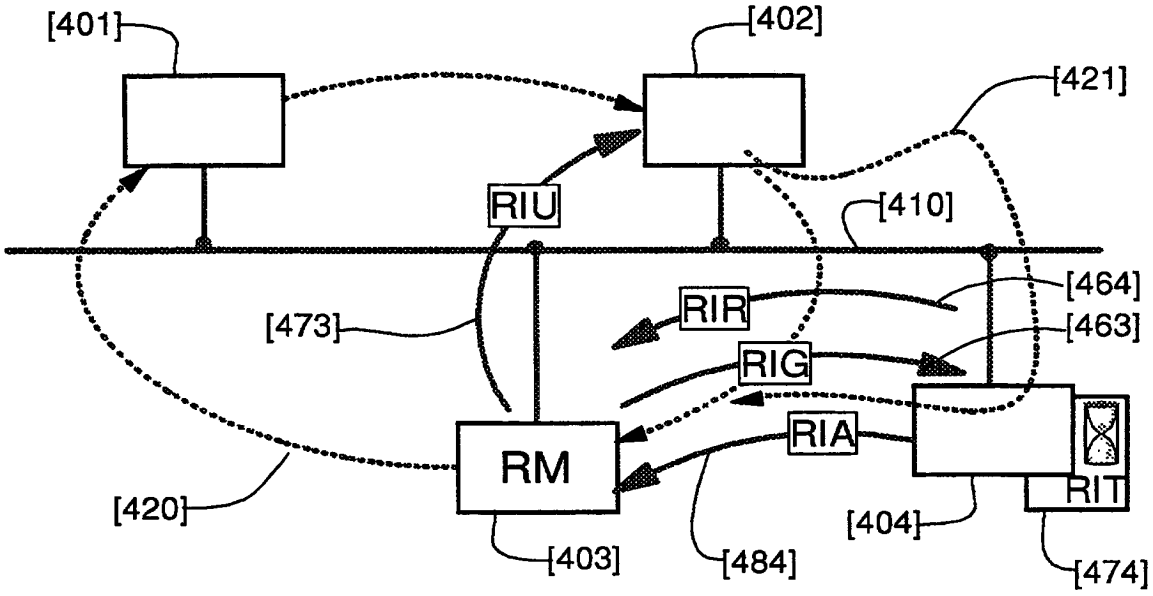

Figure 4

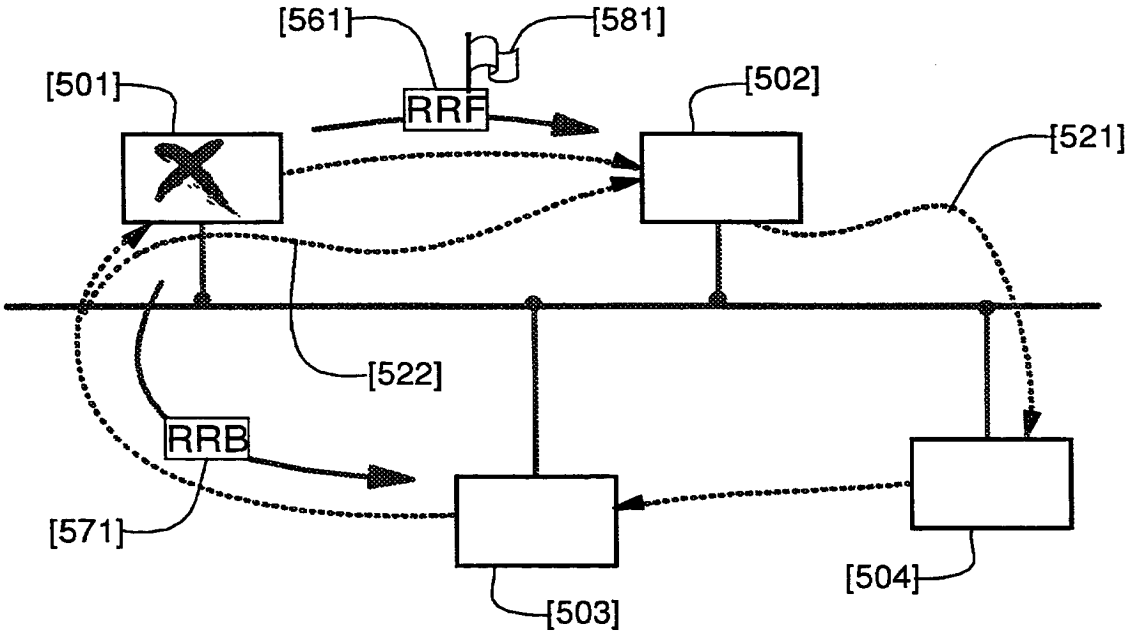

Figure 5

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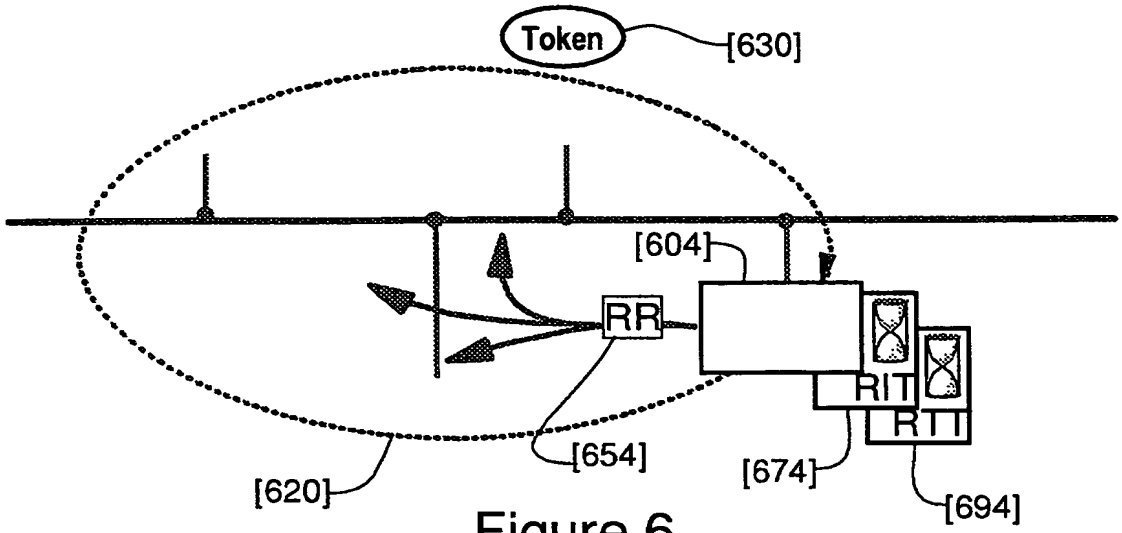

Figure 6

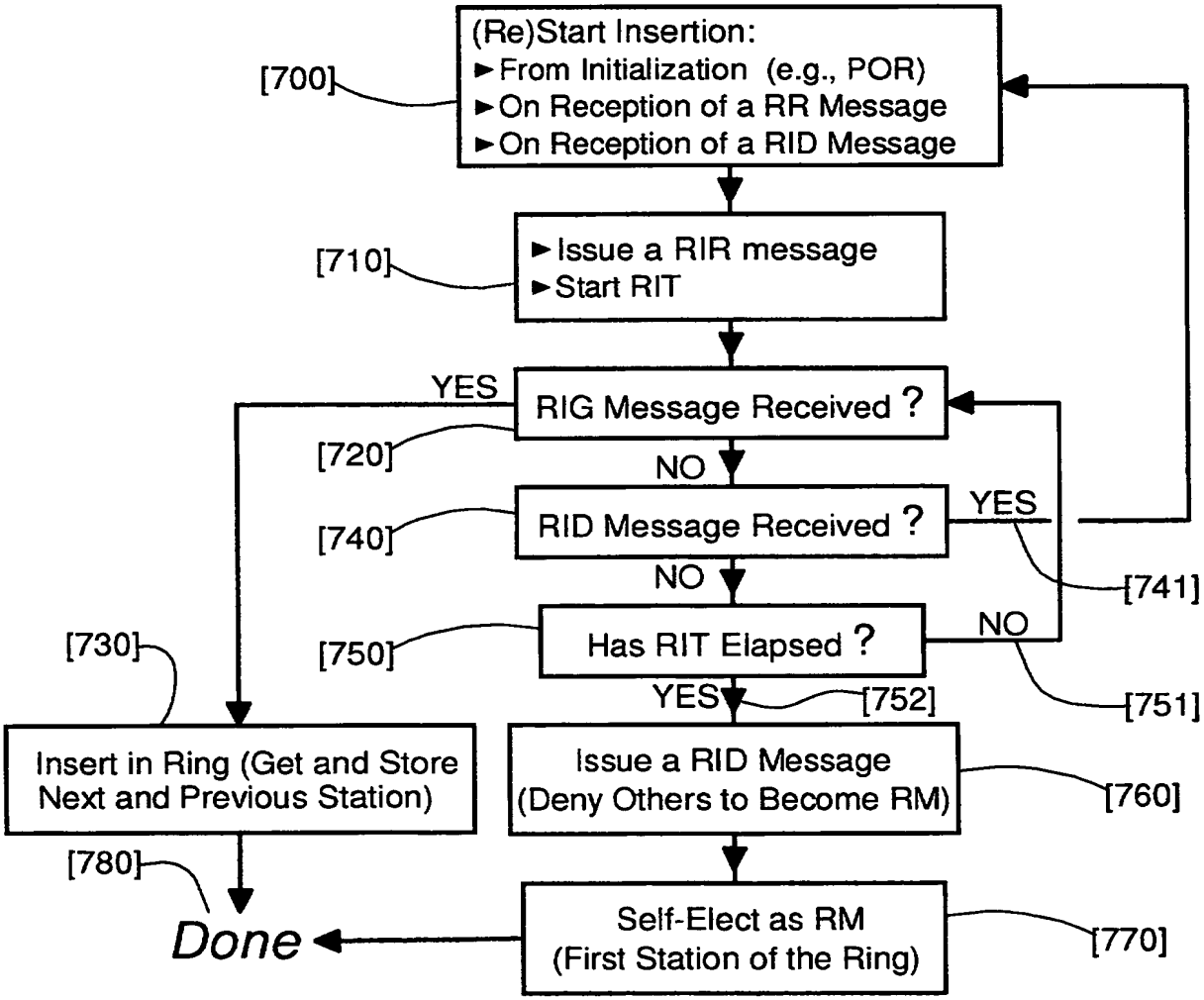

Figure 7

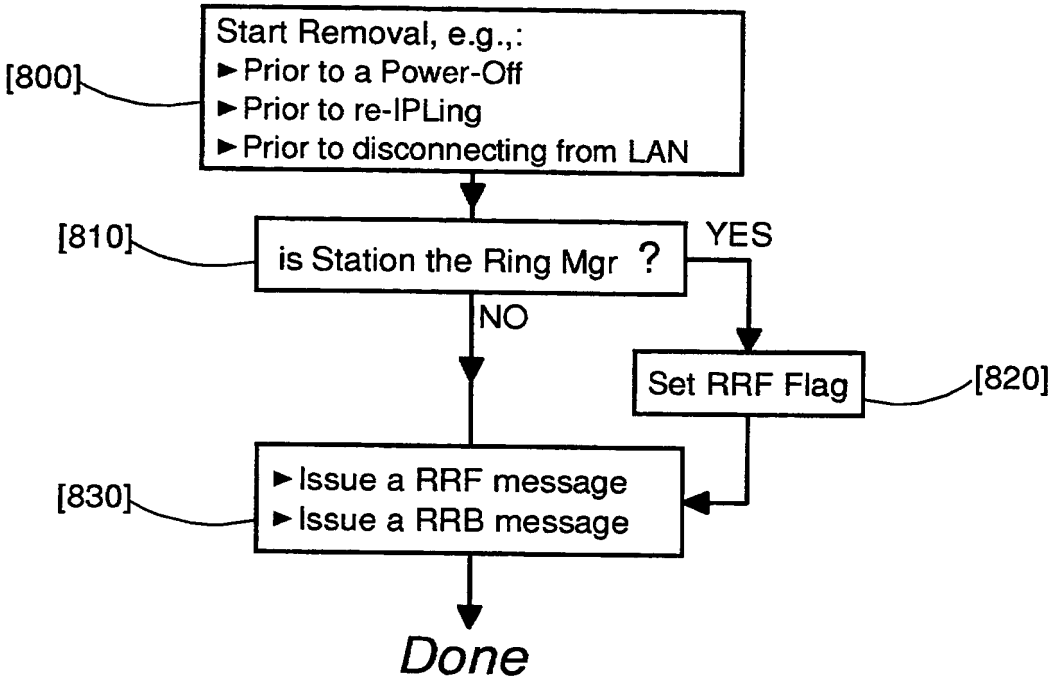

Figure 8

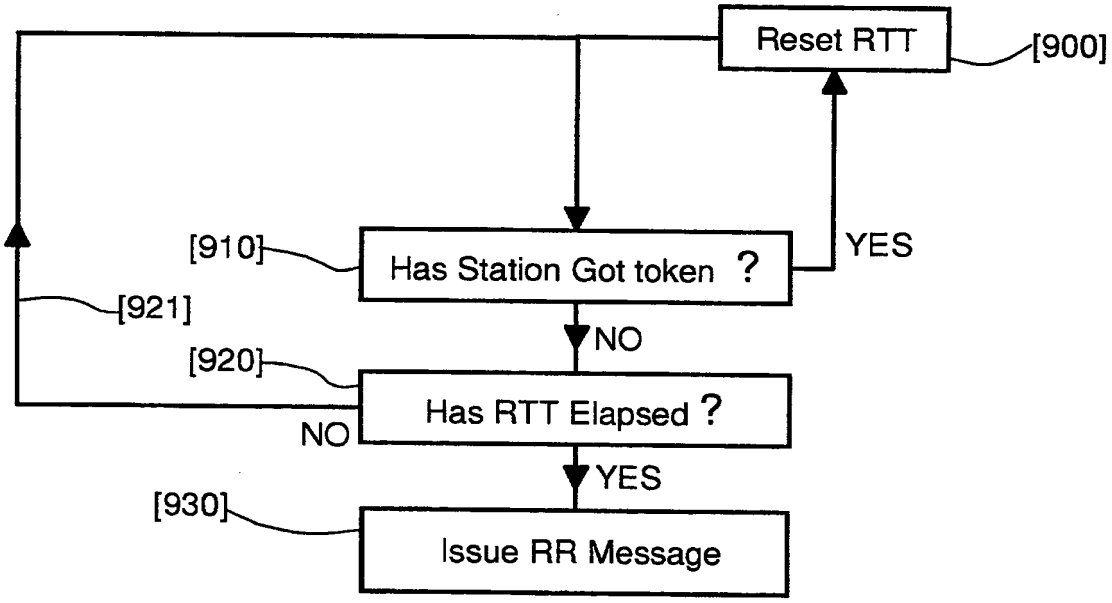

Figure 9